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THE USE OF GENERAL ALGEBRAIC MODELING SYSTEM IN ANALYZING CROP/LIVESTOCK PRODUCTION SYSTEM

A.M. Ahmed[1], M. Abo El-Wafa[2] and G. Siam[3]

1- Desert Research Center, Animal Production Dept., Cairo, Egypt, 2-German Technical Cooperation (GTZ), Cairo, Egypt, 3- Department of Economic, Faculty of Agriculture, Cairo University, Giza, Egypt

SUMMERY

Linear programming models have been widely used to determine the optimum combination of factors to achieve specific goals. Output from linear programming models is usually deterministic and static, but linking linear programming models with dynamic simulation models can change this. The objective of this study is to demonstrate the use of General Algebraic Modeling System (GAMS) in system analysis. This implies building a simulation model to simulate the behavior of complex systems and allow experimentation of different situations. This technique offers a powerful and useful tool that can help farmers in analyzing the current production system. This technique also assists the decision-maker in choosing the most efficient way to allocate scarce resources and to achieve a certain number of goals in order of their priority. Farmers usually have a number of goals, some of which may be in conflict with each other. A case study was conducted in a newly reclaimed area in Egypt in order to use GAMS in solving the problem of unequal importance of goals. Different policy scenarios were also proposed in order to help increase farm income and to improve the overall efficiency of the current crop/livestock production system. The final objective is to minimize deviation from goal targets determined by management practices.

***Keywords:** GAMS, production system, linear programming, simulation model, Egypt*

INTRODUCTION

Models are essential for understanding a livestock production system. These models represent, in a simple way, the existing knowledge of the system and their interactions, inputs and outputs, limitations and the gap in knowledge (Spedding, 1988). The purpose of model building is to improve our understanding of systems in order to operate or improve them and to construct new ones (Spedding, 1975). Linear Programming models have been widely used to determine the optimum combination of factors in order to achieve specific goals. Programming problems are concerned with efficient use or allocation of limited resources needed to meet desired objectives. Output from linear programming models is usually deterministic and static, but linking linear programming models with dynamic simulation models can change this.

Simulation models are computer programs containing mathematical equations that quantitatively describe the system under study. They are used to simulate the behavior of complex systems, and allow experimentation of different situations. White (1991) reported that simulation models could be used to compare the effect of changes in climate, management, technological innovation and system design.

The objectives of this study were to evaluate the current production system in the newly reclaimed area in Egypt by using the General Algebraic Modeling System (GAMS), assess proposed policy scenarios, and investigate its impact on the overall efficiency of the current production system.

MATERIALS AND METHODS

The study area

This study was carried out at Tahreer Province, a desert reclaimed area. The studied area is classified as semi-arid conditions. Climate is characterized by cool winters followed by hot dry summers. Rainfall varies from year to year, with the major distribution of rainfall between November and March. This area located west of the Nile Delta of Egypt at 120 km Northwest of Cairo. This area contains a variety of small-scale mixed farming systems of different farm size and type of owner. Three sites were identified according to farm size and type of farmers. In the first site (S), farmers are traditional settlers who own 5 feddans or less. In the second site (R), farmers are mainly the early-retired employees who own 8-25 feddans. In the third site (G), settlers are university graduates who own 20-30 feddans.

Data

A random sample of 155 farms was taken from all the three sites, and was visited weekly. Visits were aimed at identifying the variables and constraints which would be included in a questionnaire that contained information on available resources, farming activities, services, costs and revenues of each farm during the agricultural year October, 1995 to September, 1996. Data included the following variables: i) Production resources: farm size, family size, livestock structure and composition, and labor. ii) Animal production performance: daily milk yield, lactation period and total milk yield, iii) Crop production performance: main crops yield and by-product yield, and 4) Farm budgets: gross output, variable costs, that included hired labor, fertilizer, seed, feed, veterinary services and mechanical power, and fixed costs that included property taxes, annual installments, farm maintenance and insurance.

Data analysis

The data were analyzed by least squares techniques using General Linear Model Procedure of SAS (1998) for statistical analysis. The fixed-effects linear model was used to analyze production resources and to develop technical coefficients of livestock and crop production and level of inputs needed for each activity. These estimates were used in building up the simulation models.

Model structure

Models written in GAMS have to follow a certain basic structure. This structure is determined by a number of components. The components have a specific order: inputs that include sets, data (scalars, parameters, tables), variables, equations, and finally the outputs. More details of GAMS language are presented in GAMS, 1992.

The goal taken into consideration was to maximize the net farm income, calculated in Egyptian pounds ($ = 4.8 LE), from the available resources of the three studied sites. The net farm income is estimated as the difference between revenues and total costs. The model includes the dominant activities in the studied areas (livestock, crop, family consumption and sales activities). The objective function is expressed as follows:

Maximizing Y

$$Y = R - C - P - W - F$$

Where:

Y = annual net farm income.
R = total annual farm revenues.
C = total annual operational cost.
P = total off-farm expenditure for family consumption.
W = water cost.
F = total livestock feeding cost.

Subject to constraints:

1- Land

Represents the available cultivated land of each site.

Sum (C, Xcrop (c) * A (M, C)) =L= Land

Where:

C = cropping pattern.
Xcrop = cropping activities.
A (M, C) = period in month occupied by different crops.
Land = available land in each site.

2- Irrigation water

Total irrigation water obtained from canal or underground.

Sum (C, Xcrop * WC (M, C) = L = FLIM + Pump (M)

Where:

WC (M, C) = monthly water requirements for each crop.
FLIM = available irrigation water obtained from canals in cubic meter.
Pump (M) = available quantity of underground water.

3- Human power

This constraint represents the distribution of the human power (family and hired labor) participating in crop and livestock activities.

Sum (C, Xcrop (C) * LC (M, C)) + Sum (Xa, Xlive (Xa) * Labreq (Xa, M)) =L= Flab (M) + Tlab (M).

Where:

LC (M, C) = monthly labor required for each crop.
Xa = livestock types.
Xlive = livestock activity.
LabReq = monthly labor required for each type of livestock.

4- Family labor

Represent the total labor off-farm and on-farm and the available family labor on the farm level each month.

Flab (M) + Fout (M) = L = FAMlab

Where:

Flab = monthly family labor (man/day).

Fout = monthly off-farm jobs.

Famlab = monthly available family labor.

Simulation models

Farmer's face and manage a wide range of interrelating components in which a particular production system is located. These are: i) ecological factors which lie outside the control of the farmer; ii) socio-cultural environment (values, beliefs and customs of the society); iii) government support services and development programs; and iiii) financial environment which is considered as a source of uncertainty that affects the farmer's decisions.

According to these reasons, the study proposed different government policies scenarios and assesses the positive or negative impact on the current production system. These scenarios are: i) increasing farm gate prices of some strategic cash crops (wheat, groundnuts and maize) as a government policy aiming at encouraging farmers to extend their cultivation to decrease food gab and improve reclaimed land fertility; ii) increasing purchasing price of chemical fertilizers as it represents 25% of the total variable cost of the crops; iii) Increasing productivity of livestock of milk and meat and, at the same time, increase crops per feddan yields to be comparable with those in the old land.

Simulation techniques were used to apply the current and proposed scenarios on the models in each site. The sets of estimates produced by least squares analysis were introduced to the models that are based on GAMS. Detailed descriptions of the simulation models and constrains structure are presented in Abo El-Wafa 1997.

Indicators for the system efficiency

Barnard and Nix (1993) defined gross margin of an enterprise as its gross output (revenues) less variable cost attributed to it. Gross margin per feddan (4500 m^2) is compared with that obtained from other farms, with the comparison providing a useful idea of the production and economic efficiency of the system. The efficiency of the system was measured as the return per unit of limiting resource, which is found by dividing the gross margin by the number of resource units needed. To facilitate comparison between farms of different sizes, the results can be expressed as net profit per feddan (Boast, 1991). The changes in the efficiency of the system were measured for each site as the response to policy scenarios on the return per feddan, net profit per feddan, and output/input ratio.

RESULTS AND DISCUSSION

Base run solution

Net farm income is a composite measure, which included all the technical coefficients per animal, per feddan of different crops and price per unit of products.

The value of production is measured in terms of total gross output (revenues). The value of farm production is used because physical units (milk, meat, crops and manure) cannot be added in a meaningful way. This measure combines many different farm products into one measure.

Results of the base run solution that simulates the current production system are presented in Tables 1, 2, and 3. The study showed that factors affecting the net farm income were the value of gross output (revenues) of animal and crop production, total variable costs, and total fixed costs. But the revenues and expenditures depended mainly on farm size, in addition to cropping pattern and different variable costs needed for each crop and livestock that varied from one site to another. The (G) site earned the highest net farm income among the three studied sites.

The cropping pattern and crop size responded to a complex set of factors. The cropping pattern results from the interaction of farmers' objectives, natural factors, governmental policy, managerial capabilities and financial capacities.

Results of the base run showed that, in the (S) site, the main winter crop is wheat and potatoes, representing 25% and 75% of the farm size, respectively. Maize and summer potatoes are cultivated in summer and represented 14% and 86% of the farm size, respectively. The obtained results are mostly comparable with the real-life current production system, except for the actual area of cultivated potatoes that exceeded the area obtained from the model output. This may be due to high risk and high variable costs of cultivating potato.

Cropping pattern of the model output in the (R) site is very close to reality. Wheat, clover and cucumbers are the main winter crops and represented 15%, 70%, and 15% of the farm size, respectively. The cropping pattern obtained from the model output is very close to that obtained from the field survey. Maize and groundnuts are the main summer crops and represented 4% and 91% of the farm size, respectively. A decline of the maize cultivated area may be due to the high gross margin of the groundnuts per feddan in the model. This may lead to the reduction of the maize cultivated area to only satisfy a supply for home consumption. Also, cultivating groundnuts will provide the opportunity to utilize the entire cultivating area all year round.

In the (G) site, groundnuts are clearly the major cash crop in summer along with maize, and represented about 96% and 4% of the total cultivated area, respectively. The main winter crops are clover and wheat, representing 90% and 10%, respectively. These results are in agreement with the results of field survey. Due to high yield per feddan of groundnuts, this site is considered the highest in groundnuts production.

Proposed scenarios solution

The results of applying the proposed policy scenarios, as well as responses of the three studied sites are presented in Tables 1, 2, and 3.

In the first site (S), applying the proposed policy scenario 1, the net farm income in comparison with the base run solution, was accompanied by a very slight increase in net farm income (+ 0.2%). This was due to the small farm size. With the high cost of purchasing chemical fertilizers, the net farm income was decreased by 1.7%. These results revealed that this location is sensitive to the increasing price of chemical fertilizers, causing a negative impact on the net farm income and overall efficiency of the system. Applying scenario 3 increased both livestock and crop revenues by 22.7%, resulting in an increase of net farm income by 76%.

In the second site (R), increasing productivity of livestock and crop yield per feddan had positive impact on the net farm income, estimated as 101% in comparison to the base run solution. Scenario 1 resulted in a positive response of 8.6%. Scenario 2 had a negative effect on the net farm income among all the studied sites due to its larger farm size.

In the third site (G), increasing productivity of livestock and crop yield per feddan had positive impact on the net farm income estimated as 100% in comparison to the base run solution. Scenario 1 resulted in a positive response of 6.6%. Scenario 2 had a negative effect on the net farm income.

Table 1. Results of simulation solution for base run and proposed policy scenarios in (S) site

Item	Base Run	Scenario 1		Scenario 2		Scenario 3	
		Value	%*	Value	%*	Value	%*
Revenues	38330	38366	+ 0.1	38330		47018	+ 22.7
Variable cost	16485	16485		16753	+ 1.6	13359	- 18.9
Gross margin	21845	21881	+ 0.2	21577	- 1.2	33659	+ 54.1
Fixed cost	6333	6333		6333		6333	
Net farm income	15512	15548	+ 0.2	15244	- 1.7	27326	+ 76
Efficiency of the system:							
Return/feddan	4780	4788		4721		7365	
Net profit/feddan	3394	3402		3336		5979	
Output/input ratio**	2.33	2.33		2.29		3.52	

* Percentage of positive/negative response in comparison with base run.

** The reward of one unit of money spends (value of revenues divided by variable costs).

Table 2. Results of simulation solution for base run and proposed policy scenarios in (R) site

Item	Base Run	Scenario 1		Scenario 2		Scenario 3	
		Value	%*	Value	%*	Value	%*
Revenues	43443	44369	+ 2.1	43443		60614	+ 39.5
Variable cost	16462	16462		16665	+ 1.5	11700	- 28.9
Gross margin	26981	27907	+ 3.4	26778	- 0.8	48914	+ 81.3
Fixed cost	5448	5448		5448		5448	
Net farm income	21533	22459	+ 4.3	21330	- 0.9	43466	+ 101
Efficiency of the system:							
Return/feddan	1955	2022		1940		3544	
Net profit/feddan	1560	1627		1546		3150	
Output/input ratio**	2.64	2.69		2.61		5.18	

* Percentage of positive/negative response in comparison with base run.

** The reward of one unit of money spends (value of revenues divided by variable costs).

Table 3. Results of simulation solution for base run and proposed policy scenarios in (G) site

Item	Base Run	Scenario 1		Scenario 2		Scenario 3	
		Value	%*	Value	%*	Value	%*
Revenues	60470	62512	+ 3.4	60470		85685	+ 41.7
Variable cost	22667	22667		22882	+ 0.9	16630	- 26.6
Gross margin	37803	39845	+ 5.4	37588	- 0.6	69055	+ 82.7
Fixed cost	6656	6656		6656		6656	
Net farm income	31147	33189	+ 6.6	30932	- 0.7	62399	+ 100
Efficiency of the system:							
Return/feddan	2452	2584		2438		4478	
Net profit/feddan	2010	2152		2006		4047	
Output/input ratio**	2.66	2.75		2.64		5.15	

* Percentage of positive/negative response in comparison with base run.

** The reward of one unit of money spends (value of revenues divided by variable costs).

Efficiency of the production system

Comparing base run solutions at the farm level among the three studied sites revealed that farmers of the first site (S) utilized available resources in a more efficient way than the other two sites. Value of return per unit of feddan revealed that scenario 3 had the highest return among all proposed policy scenarios studied, indicating greatest efficiency of land use. Scenario 3 had a highly positive impact in the all studied areas, but response varied in its magnitude from one site to another.

CONCLUSION

Results of the present study revealed that modeling with the aid of General Algebraic Modeling System (GAMS) is a useful tool for farmers and decision-makers. Such technique provides full information about the impact of proposed policy on the net farm income before the implementation. The results also showed that the application of the same scenario in different sites has different impact on the net farm income and efficiency of the production system due to the availability of production resources in each location.

It is of great interest to notice that the response of different policy scenarios did not have the same effects on the net farm income in all of the three studied sites. The different response could be attributed to the differences of the major characteristics, production resources (e.g. farm size, herd size and structure), cropping pattern, management practices and different constraints pertained in each site.

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استخدام النظام الجبرى العام للنمذجة فى تحليل نظام الإنتاج النباتى / الحيوانى.

على مصطفى أحمد[1] ، محمد أبوالوفا[2]، جمال صيام[3]

١ - مركـز بحوث الصحراء، المطرية، مصر، ٢ - الوكالة الألمانية للتعاون الفنى، الدقى، مصر، ٣ - قسم الاقتصاد الزراعى، كلية الزراعة، جامعة القاهرة،الجيزة، مصر.

يستخدم أسلوب البرمجة الخطية على نطاق واسع لتحديد التوليفة المثلى من العوامل لتحقيق أهداف محددة. ناتج البرمجة الخطية عادة ما يكون مؤكد وثابت. ولكن يمكن تغيير ذلك بربط نماذج البرمجة الخطية بنماذج محاكاة ديناميكية، وهذا يستلزم بناء نموذج لمحاكاة سلوك نظم الإنتاج وتجربة عدة مواقف مختلفة. يعطى هذا الأسلوب أداه قوية ونافعة يمكن عن طريقها مساعد الفلاحين فى تحليل نظام الإنتاج الحالى وكذا متخذى القرار فى اختيار أكفأ الطرق لتخصيص الموارد النادرة لتحقيق عدة أهداف محددة طبقا لأولويات مختلفة. وعادة الفلاحين لديهم أهداف عديدة وأحيانا بعضها متضارب. تم إجراء دراسة حالة فى مديرية التحرير، منطقة حديثة الاستصلاح، فى مصر لتحليل نظام الإنتاج باستخدام النظام الجبرى العام للنمذجة وتم اقتراح عدة سيناريوهات لتنمية وزيادة الدخل المزرعى ولتحسين كفاءة نظام الإنتاج الحالى.